Economic Evaluation of the Effects of Planting Date and Application Rate of Imidacloprid for Management of Cereal Aphids and Barley Yellow Dwarf in Winter Wheat

T. A. ROYER, K. L. GILES, T. NYAMANZI,[1] R. M. HUNGER, E. G. KRENZER,[2] N. C. ELLIOTT,[3] S. D. KINDLER,[3] and M. PAYTON[4]

Department of Entomology and Plant Pathology, Oklahoma State University, 127 NRC, Stillwater, OK 74078

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ABSTRACT The effects of planting date and application rate of imidacloprid for control of *Schizaphis graminum* Rondani, *Rhopalosiphum padi* L. (Homoptera: Aphididae), and barley yellow dwarf virus (BYDV) in hard red winter wheat were studied. The first experiment was conducted from 1997 to 1999 at two locations and consisted of three planting dates and four rates of imidacloprid-treated seed. The second experiment was conducted from 2001 to 2002 in Stillwater, OK, and consisted of two varieties of hard red winter wheat seed and four rates of imidacloprid. Aphid densities, occurrence of BYDV, yield components, and final grain yield were measured, and yield differences were used to estimate the economic return obtained from using imidacloprid. In the first study, aphid populations responded to insecticide rate in the early and middle plantings, but the response was reduced in the late planting. Yields increased as insecticide rate increased but did not always result in a positive economic return. In the second study, imidacloprid seed treatments reduced aphid numbers and BYD occurrence, protected yield, and resulted in a positive economic return. The presence of aphids and BYDV lowered yield by reducing fertile head density, total kernel weight, and test weight. Whereas the application of imidacloprid seed treatments often provided positive yield protection, it did not did not consistently provide a positive economic return. A positive economic return was consistently obtained if the cereal aphid was carrying and transmitting BYDV and was more likely to occur if wheat was treated with a low rate if imidacloprid and planted in a "dual purpose" planting date window.

KEY WORDS *Schizaphis graminum*, *Rhopalosiphum padi*, chemical control, economics

Hard red winter wheat, *Triticum aestivum* L., is the most widely grown crop in Oklahoma; >2.6 million ha is planted each year (Oklahoma Department of Agriculture 2002). In Oklahoma and parts of Kansas and Texas, winter wheat is grown for grain; for forage, which is used to feed to cattle during the fall and winter; or for forage plus grain, which is known as "dual purpose" wheat (Epplin et al. 1996, True et al. 2000). Because winter wheat is grown for different purposes, individual wheat fields are planted from mid-August to early December, depending upon location (Epplin et al. 1996, Krenzer 2000a). In central Oklahoma, early planting (late August–early September) allows for the maximum accumulation of fall forage that can be used as pasture or hay for cattle but that significantly lowers grain yield potential and quality (Krenzer 1995, 1997). Dual purpose wheat is typically planted from mid-late September to reduce the deleterious effects of early planting on grain yield potential while producing adequate forage for fall pasture (Epplin et al. 1996, 2001). If the crop is intended for grain production only, it is usually planted from early to mid-October. In dual purpose systems, grain yields are typically 10–20% lower than yields in a grain-only system (Krenzer 1995).

The bird cherry-oat aphid, *Rhopalosiphum padi* (L.), and the greenbug, *Schizaphis graminum* (Rondani), are important pests of winter wheat in Oklahoma and the Southern Plains (Royer et al. 1997). Both species can significantly limit profitable wheat production (Starks and Burton 1977, Webster 1995), either through direct feeding (Kieckhefer and Kantack 1980, 1988; Kieckhefer and Gellner 1992; Kieckhefer et al. 1994; Riedell and Kieckhefer 1995; Kindler et al. 2002) or by transmitting barley yellow dwarf virus (BYDV), a luteovirus that infects cereal grains (Araya et al. 1987, Wiese 1987). There are five prominent strains of BYDV that can be transmitted by >23 aphid species: BYD-MAV, BYD-PAV, BYD-RMV, BYD-RPV, and BYD-SGV (D'Arcy 1995). Each strain is differentiated by how efficiently it is transmitted by

[1] Heifer Intl. 1015 Louisiana, Little Rock AK 72202.

[2] Department of Plant and Science, Oklahoma State University, Stillwater, OK 74078.

[3] Plant Science and Water Conservation Research Laboratory, USDA–ARS, 1301 N. Western St., Stillwater, OK 74078.

[4] Department of Statistics, Oklahoma State University, Stillwater, OK 74078.

Table 1. Greenbug, bird cherry-oat aphid, and total aphid infestation intensity (± SEM) and population composition in untreated plots in date of planting trials conducted in Lahoma and Perkins, OK, 1997–1999

Location	Planting	Seasonal mean no. aphids/0.3-m row	Greenbug-days	BCO days	Aphid-days	GB/BCO ratio
Lahoma	11 Sept. 97 (early)	23.39	1044.0 (104.0)	1826.8 (340.5)	2870.8 (325.9)	0.57
	29 Sept. 97 (middle)	19.59	537.7 (53.5)	1521.4 (124.1)	2059.2 (168.0)	0.35
	10 Oct. 97 (late)	6.50	192.1 (58.2)	592.3 (97.6)	784.4 (131.2)	0.32
	15 Sept. 98 (early)	4.60	36.1 (26.7)	146.8 (24.5)	182.9 (50.9)	0.24
	29 Sept. 98 (middle)	13.49	35.5 (9.42)	428.75 (36.69)	464.25 (30.06)	0.22
	13 Oct. 98 (late)	18.02	97.8 (25.7)	500.5 (65.7)	598.3 (82.8)	0.20
Perkins	10 Sept. 97 (early)	23.41	1633.0 (245.7)	626.8 (106.3)	2259.8 (323.8)	2.60
	22 Sept. 97 (middle)	15.27	1101.8 (90.3)	675.3 (31.2)	1777.0 (62.0)	1.63
	8 Oct. 97 (late)	5.75	338.5 (39.7)	200.3 (53.6)	538.8 (88.2)	1.69
	13 Sept. 98 (early)	16.75	909.3 (542.6)	1373.6 (448.8)	2282.9 (491.2)	0.66
	28 Sept. 98 (middle)	17.01	645.9 (39.4)	1248.4 (119.1)	1894.4 (113.6)	0.52
	13 Oct. 98 (late)	10.42	506.6 (171.3)	674.3 (235.6)	1180.9 (266.4)	0.75

BCO, bird cherry-oat; GB, green bug; early, forage only; middle, forage + grain; and late, grain only.

one of five common cereal aphids, and how virulent it is to 'Coast Black' variety oats (Wiese 1987). Researchers have demonstrated that BYDV infections can cause severe yield loss to hard red winter wheat (Fitzgerald and Stoner 1967, Carrigan et al. 1981, Riedell et al. 1999). In the U.S. Southern Plains and upper Midwest, the BYD-PAV strain is the most prevalent and probably the most devastating (Gourmet et al. 1996).

Early-planted wheat is more likely to be inhabited and damaged by several insect pests (Hatchett et al. 1987), including cereal aphids (Pike and Schaffner 1985, Brooks et al. 2003) because its early growth occurs when temperatures are warmer and arthropod activity is higher. In addition, the crop is at greater risk of being infected with the aphidborn BYDV (McGrath and Bale 1990, Hammon et al. 1996, Chapin et al. 2001), which is associated with fall virus transmission by *R. padi* (Halbert and Pike 1985, Clement et al. 1986, Araya et al. 1987). *R. padi* and *S. graminum,* although different in their transmission efficiency, are important vectors of the BYD-PAV strain (Power and Gray 1990). Control of cereal aphids and BYDV is complex and relies on the combined use of resistant or tolerant varieties, delayed planting in the fall, use of use of insecticides to prevent or reduce the infestation of the aphid vectors, or a combination.

Generally, attempts to manage BYDV by controlling aphids with foliar insecticide applications are not effective because the insecticide is often applied after aphids have established and transmitted the virus into the plant (Kendall et al. 1985, Gray et al. 1996). A seed treatment using the chloronicotinyl insecticide imidacloprid can control early-season infestations of cereal aphids in winter wheat (Gray et al. 1996, Wilde et al. 2001) and prevent or reduce the spread of BYDV by killing the aphids before they transmit the virus into the host wheat plant (Gourmet et al. 1996, Gray et al. 1996, Hunger et al. 1997, McKirdy and Jones 1996).

Although effective at reducing aphid infestations and spread of BYDV, the prophylactic use of imidacloprid seed treatment does not always provide a consistent economic benefit to grain production (Hunger et al. 1997, Wilde et al. 2001). However, imidacloprid was not evaluated in early-planted winter wheat systems (e.g., forage only, dual purpose) that are more likely to be colonized by aphids in the fall.

The objectives of this study were to evaluate the effect of planting date and insecticide rate of seed treated with imidacloprid on abundance of *S. graminum, R. padi,* and incidence of BYDV in hard red winter wheat and to evaluate the economic impact to grain production that results from the interaction of these pest management tactics.

Materials and Methods

Insecticide Rate/Date of Planting Studies for Aphid Control, 1997–1999. These experiments were designed to measure the effects of four rates of imidacloprid seed treatments in three representative planting dates for 1) control of cereal aphids and 2) the grain yield response that resulted from that control. Identical field plots (except for the randomization pattern and slight differences in specific planting dates) were established from 1997 to 1999 at the North Central Research Station, Lahoma, OK, and the Oklahoma Fruit Research Station, Perkins, OK. The land used in the study had been planted into continuous wheat grown under conventional tillage practices. Soil types were a Grant silt loam (Lahoma station) and a Novina loam (Perkins station).

The experiment at each site/year was arranged in split plot design with four replications. Planting date was the main factor and insecticide rate as the subfactor. The main factor was arranged in a randomized complete block structure. Individual plots measured 1.8 by 12.2 m with a 0.08-m border between plots. Specific planting times are footnoted in Table 1. The planting dates were selected to correspond to average planting times for forage (early planting), forage + grain (middle planting), and grain only (late planting) production (Table 1 for exact planting dates). Four rates (0.0, 0.24, 0.48, or 0.96 g [AI]/kg seed) of imidacloprid-treated seed were evaluated for each planting date. The middle and high rates fell within the minimum and maximum labeled rate of this product. The hard red winter wheat seed '2137' was treated by diluting imidacloprid (Gaucho 480 FS, Gustafson LLC, Plano, TX) in a 1:10 aqueous solution and dispersing the solution onto 3.2-kg seed lots for 1–2 min with a Hege seed treater (Hege USA, Colwich, KS). Wheat seed was drilled at a rate of 67 kg/ha in rows spaced 17.8 cm apart. Plots were fertilized at planting to attain a yield potential of 33.60 quintals/ha (Johnson 1987).

Plots were sampled every ≈14–28 d for aphids by dislodging all aphids in a 0.3-m section of row into a plastic dishpan. Two subsamples were collected from the four center rows of each plot after the plants reached the two-leaf stage. Aphid days, a relative method of estimating aphid feeding intensity, were calculated for *S. graminum* and *R. padi* in each treatment by using the formula $\Sigma\ P_n + [P_{n+1} - P_n/D * D_{P_n > n+1}]$, where P is mean aphid density at sample n, and D is the number of days from P_n to P_{n+1} (Ruppel 1983). When the crop matured, yield samples were harvested with a Hege plot combine equipped with a seed cleaner and a sack to collect grain from each plot. Grain weight and moisture were measured, and yields were adjusted to 13.5% moisture content. Yield protection from insecticide treatment was measured as the difference between the mean yield of the untreated control and each insecticide seed treatment.

Insecticide Rate Study for BYDV, Control, 2001–2002. An additional field trial was conducted in 2001–2002 at the Entomology and Plant Pathology Research Farm located west of Stillwater, OK, to evaluate the effects of insecticide rate on incidence of BYDV and resulting yield in winter wheat. The site was chosen because aphid numbers and BYDV consistently occurred (B. Hunger, unpublished data). 'Karl 92' and '2174' hard red winter wheat were treated with one of four rates of imidacloprid (0.0, 0.32, 0.48, or 0.64 g [AI]/kg seed) as described previously, and planted as described previously on 13 September 2004 in plots measuring 4 by 9 m and arranged in a randomized complete block design with four replications. The planting date was selected to maximize the potential for BYDV infections. The planting date falls near the late end of the planting date range for forage-only wheat. Plots were fertilized at planting to attain a yield potential of 33.60 quintals/ha (Johnson 1987). Azoxystrobin (Quadris; Flowable, Syngenta Inc., Greensboro, NC) was applied at 657 ml product/ha in the spring to control foliar fungal pathogens.

Aphid incidence, BYDV incidence, fertile head count (FHC), grain weight, and test weight (TW) were recorded for analysis. Aphid abundance was determined three times during the growing season by counting the number of aphids in one randomly selected 0.3 m of row in each plot as described previously. Because plots were sampled infrequently, aphid days were not calculated, but instead, relative differences in aphid abundance were used to compare treatment effects. BYDV incidence was determined by estimating the area within each plot that exhibited symptoms (purpling, yellowing, stunting, or a combination).

Presence of BYDV in foliage was confirmed with the enzyme-linked immunosorbent assay (ELISA) by using polyclonal antibodies in a double antibody sandwich test (AGDIA Inc. Elkhart, IN), following the guidelines proposed by Sutula et al. (1986). Three to five symptomatic leaves (flagleaf minus 2) were collected from plots exhibiting symptoms, and asymptomatic leaves were collected from plots with no BYD symptoms and stored at −80C until assayed. Samples were tested for BYD-RPV and BYD-PAV strains only because prior testing over the years in Oklahoma indicated that these strains are the most common in Oklahoma (B. Olson and R.M.H., unpublished data). A negative-positive threshold was established by adding three standard deviation units to the average of the negative controls, known uninfected wheat foliage, as outlined by Sutula et al. (1986). Values that exceeded this threshold were considered positive and values less than this threshold were considered negative.

The number of fertile heads per 0.3-m row was counted before harvesting the grain. Plots were harvested using a Hege small plot combine harvester with a seed cleaner and a sack to collect grain from each plot. Total grain weight was measured for each plot, and a subsample was collected to measure TW.

Data Analysis. Aphid counts were transformed to log $(x + 1)$ before statistical analysis to homogenize variances, however, results are presented in original scale. Yields were adjusted to 13.5% moisture for estimation. Data were analyzed using PROC MIXED (Littell et al. 1996) by using the appropriate analysis of variance (ANOVA) model (split plot or randomized complete block). For purposes of analysis, we assigned block, location, and year as random effects and planting date and insecticide rate as fixed effects for the insecticide rate/rate of planting studies, and block as a random effect and variety and seed treatment rate as a fixed effect for the insecticide rate/BYDV study. Economic benefits resulting from the seed treatment were determined by estimating the value of yield differences from treated plots compared with the untreated plot after subtracting the cost of the seed treatment. Grain sales price was estimated by taking a 7-yr (1995–2001) average of grain price reported for Oklahoma (Oklahoma Department of Agriculture 2002). Insecticide cost was estimated by averaging the cost estimates obtained from three commercial suppliers within Oklahoma as of 2002. Profit and loss were estimated in two ways: as actual profit or loss and based on statistical differences between treatments (Pilcher and Rice 2003). Significance for statistical analysis was set at $P = 0.05$.

Results

Insecticide Rate/Date of Planting Studies for Aphid Control. Seasonal history of aphid abundance at each location/year is shown in Fig. 1. Aphid populations were composed of a mixture of *R. padi* and *S. graminum* at both locations, but *S. graminum* was more

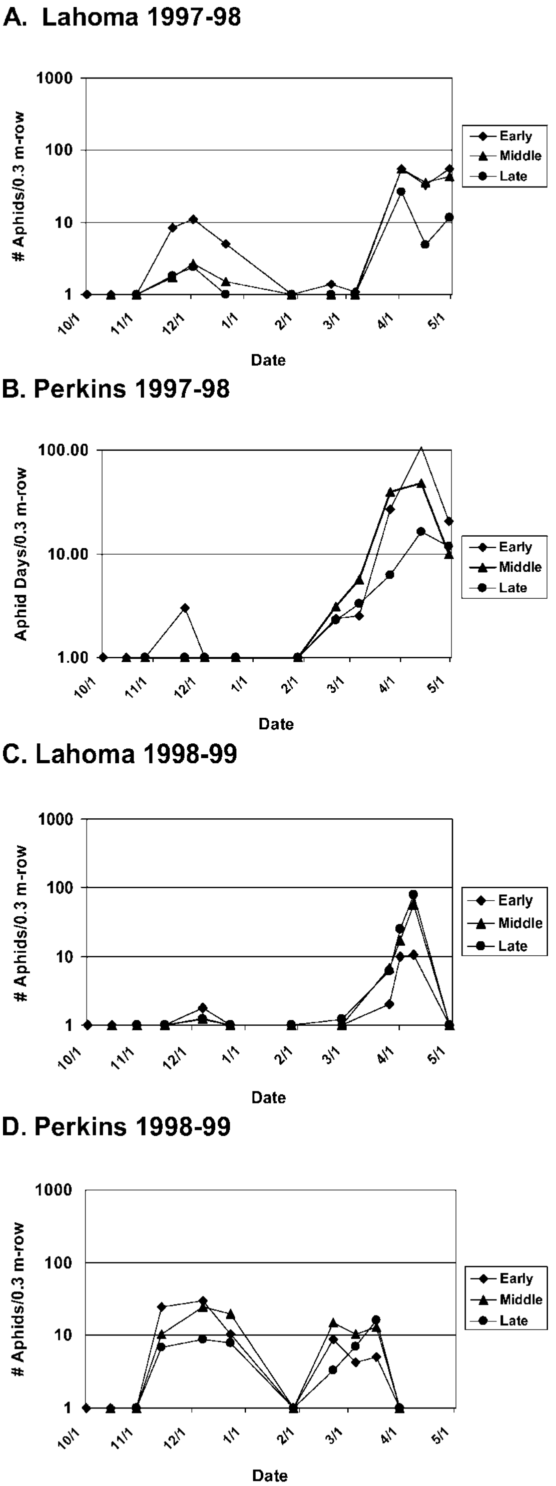

Fig. 1. Seasonal abundance of cereal aphids (*S. graminum* + *R. padi*) in the untreated plots in the date of planting study, Lahoma (A and C) and Perkins, OK (B and D), 1997–1999. Early, planted between 10 and 15 September; middle, planted between 22 and 29 September; and late, planted between 8 and 13 October.

numerous in Perkins in 1997–1998, whereas R. *padi* was more numerous in Perkins 1998–1999 and in both years in Lahoma (Table 1).

Aphid feeding intensity, as reflected by aphid days, significantly responded to planting date ($P < 0.001$) and insecticide rate ($F = 0.005$). Aphid day intensity was highest in the early plantings and lowest abundance in the late plantings, with the exception of Lahoma in 1998–1999, where aphid abundance was greater in the middle and late planting (Table 1). The effect of rate of imidacloprid seemed to provide a consistent trend of aphid control, with control increasing as rate increased. However, there was a significant ($P < 0.001$) interaction between planting date and rate with regard to aphid feeding intensity (Table 2). When trends were evaluated within each planting date, in the middle planting, aphid abundance in the low rate was not significantly different from the untreated control. In the late planting, aphid abundance in the low and middle rates did not differ from the untreated control. (Table 3). Grain yields were significantly ($P < 0.01$) different among planting dates and insecticide rates, and there was no interaction among planting date and insecticide rate. Grain yield increased as planting date was delayed and as insecticide rate increased. However, the yield protection provided by the insecticide did not always translate into positive economic return (Table 3). The lowest insecticide rate was the only rate that provided a positive economic benefit across planting dates. A breakdown of economic returns by planting date revealed that imidacloprid provided a positive economic return for the middle planting only and that a positive return was consistently obtained only from the low and middle rates.

Insecticide Rate Study for BYD Control. Aphid populations consisted primarily of *R. padi*. Populations were first observed in November and reached densities of >100 aphids/0.3-m row in all control plots (Table 4). To evaluate presence of the BYD-PAV and BYD-RPV in the wheat plots, a negative/positive threshold value was established for testing with ELISA by using three healthy (uninfected wheat) controls. The threshold value was 0.2327, which was calculated by adding three standard deviations units (3 by $0.0268 = 0.0804$) to the mean value from ELISA that was measured on three healthy, uninfected plants $((0.182 + 0.130 + 0.1523) \div 3) = 0.1523$. The threshold value was $0.1523 + 0.0804 = 0.2327$. This threshold was used for both strains of virus, but results indicated that the BYD-PAV strain was most common.

There were significant differences in aphid abundance between varieties at several rates (Table 4), but there were no significant interactions (rate × variety) for any parameter so data from both varieties were combined. Aphid abundance ($F = 290.1$; df = 3, 18; $P < 0.001$), TW ($F = 22.7$; df = 3, 18; $P < 0.001$), FHC ($F = 23.6$; df = 3, 18; $P < 0.001$), and yield ($F = 18.9$; df = 3, 18; $P < 0.001$) responded to insecticide rates. Aphid abundance and the incidence of BYDV was reduced as insecticide rate increased (Table 4), whereas all yield components and grain yield increased as insecticide

Table 2. ANOVA results (MIXED PROC, split plot model; SAS Institute) for control of aphids and subsequent yield response to wheat treated with imidacloprid at three planting times

Response variable	Source of variation	Test of fixed effects		
		df	F	$P > F$
Aphid days	Planting date	2, 30	10.57	0.0002
	Insecticide rate	3, 135	35.65	<0.0001
	Planting date × insecticide rate	6, 135	4.20	0.0007
Yield	Planting date	2, 30	22.01	<0.0001
	Insecticide rate	3, 135	6.31	0.005
	Planting date × insecticide rate	6, 135	1.09	0.3714

rate increased. Grain yield protection translated into a substantial positive economic return, and the trend was that greater returns were obtained as imidacloprid rates increased (Table 5).

Discussion

Use of a prophylactic insecticide application is not usually viewed as a desirable integrated pest management (IPM) tactic. Yet, seed treated with imidacloprid has many environmentally and economically desirable qualities (e.g., low application rate, minimal worker exposure hazard, prevention of a virus disease to the crop). If deployed prudently, an insecticide seed treatment offers a sensible tool to use in an IPM program. These data show how difficult it is to predict whether a prophylactic insecticide seed treatment will consistently pay for itself. If aphid pressure and incidence of BYDV are sizeable enough (as seen in the Stillwater study), a seed treatment will provide more than enough yield protection to obtain economic benefit from their application. However, the data suggest that in the absence of high levels of BYDV, the economic return is much less certain.

Results in this study indicated that the lowest rate of imidacloprid provided the most consistent economic return. Further analysis shows that the economic returns occurred in the middle planting, even though the low rate in that middle planting did not measurably reduce aphid days compared with the untreated plots (Table 3). An examination of aphid densities in the middle planting (Fig. 2) shows that aphid numbers in the untreated plots were higher than the seed treatment plots in the fall but difficult to statistically separate from the each other. Studies by Kieckhefer and Gellner (1992) and Kindler et al. (2002) indicated that wheat seedlings infested by aphids early in the growing season were sensitive to

Table 3. Effects of imidacloprid rate and planting date on aphid day accumulation, yield, and economic return in date of planting studies conducted in Lahoma and Perkins, OK, 1997–1999

Planting	Insecticide rate (g [AI]/kg seed)	Aphid days[a]	Yield (quintals/ha)	Profit (loss)[b]			Avg statistical[c] profit (loss)
				Low	High	Avg	
Early	Untreated	1899	31.86				
	0.24	1182*	31.66	($14.89)	($16.51)	($15.70)	($13.25)
	0.48	909.8*	32.60	($20.49)	($14.51)	($17.51)	($26.50)
	0.96	523.0*	33.41	($40.44)	($27.94)	($34.19)	($53.00)
Middle	Untreated	1671.3	35.23a				
	0.24	1431.1	38.31b	$11.86	$36.85	$24.35	$24.35
	0.48	853.4*	39.59b	$8.98	$44.30	$26.64	$11.10
	0.96	525.7*	39.13b	($21.34)	$10.18	($5.57)	($15.40)
Late	Untreated	775.6	37.98a				
	0.24	549.8	38.99a	($5.06)	$3.08	($0.99)	($13.25)
	0.48	567.2	38.99a	($18.31)	($10.15)	($14.23)	($26.50)
	0.96	365.7*	40.67b	($31.16)	($9.42)	($20.29)	($20.29)
Combined	Untreated	1448.8	35.05a				
	0.24	1054.6*	36.32b	($2.55)	$8.10	$2.78	$2.78
	0.48	776.8*	37.06bc	($11.20)	$4.00	($3.61)	($10.47)
	0.96	471.4*	37.73c	($30.94)	($8.99)	($19.96)	($35.66)

Early, forage only; middle, forage + grain; and late, grain only.

[a] Means within a column followed by an asterisk * are significantly different (P |t| < 0.05) from the corresponding untreated mean in the assigned planting date. Means within a column followed by the same letter are not significantly different ($P < 0.05$; PROC MIXED, SAS Institute 1999).

[b] Profit (loss) is calculated by subtracting the untreated yield from the treated yield in quintals/hectare, multiplying the difference by the low ($8.11), high ($16.18), and average ($12.15) prices that winter wheat sold for in Oklahoma from 1995 to 2001 and subtracting the cost of the seed treatment ($13.25, $26.50, or $53.00/ha).

[c] Statistical profit (loss) is calculated if yield differences are significantly (P |t| < 0.05) different from the untreated plots and each other. If different, then the difference is multiplied by the average ($12.15) price that winter wheat sold for in Oklahoma from 1995 to 2001, and then subtracting the cost of the seed treatment. If a statistical difference was observed from the untreated check, but not among treatments, then the assigned profit (loss) is the value of the lowest significant difference in yield minus the cost of the seed treatment. If no statistical difference was observed from the untreated plots, then the profit (loss) is the cost of the seed treatment.

Table 4. Effects of imidacloprid and planting date on aphid abundance (aphids/0.3- m row) at Stillwater, OK 2001–2002

Sampling date	Cultivar	Insecticide rate g (AI)/kg seed			
		0.0[a]	0.32	0.48	0.64
20 Nov. 2001	Karl 92	129.8a	59.0b	30.8c	21.0d
	2174	111.3a	45.5b	*1.0c	*0.8c
20 Dec. 2001	Karl 92	276.8a	103.3b	27.0c	24.5c
	2174	227.3a	*49.0b	*1.0c	*0.0c
20 April 2002	Karl 92	129.5a	69.0b	33.3c	22.0d
	2174	117.3a	*44.8b	*10.5c	*0.0d

[a] Means preceded by an asterisk compare varieties within the same sample date, and are significantly different. Means within a row followed by the same letter are not significantly different ($P = 0.05$) based on the least-squares means (LS MEANS) test.

yield loss. A possible explanation is that all seed treatment rates provided enough yield protection early in the growing season to provide an economic benefit despite the statistically unmeasurable differences in aphid numbers.

As stated above, overall aphid abundance in the Lahoma 1998–1999 plots were dissimilar to historic trends, with lowest aphid numbers occurring in the early planting, and increasing numbers occurring in the middle and late planting. The population trends depicted in Fig. 1C show that aphids were virtually nonexistent until late spring and most of the aphid population buildup occurred well after 1 March. Typically, aphids colonizing wheat in late spring would encounter a more mature less hospitable host in the early planting compared with the other plantings and would be less able to build up into damaging numbers. Also, the insecticide contained within the plants would almost certainly have dissipated in all plantings to the point that they would not affect aphids that were colonizing the crop.

The explanation as to why seed treatments seem to be more economically efficient in the middle plantings is directly related to predictable wheat development (Krenzer 1995, 2000b). Early-planted wheat is vulnerable to fall aphid infestations. However, in the absence of BYDV, its yield potential is lowered enough by the early planting time that it would not benefit from the protection provided by the seed treatment. Late-planted wheat is likely to escape a fall aphid infestation and thus would not benefit as much from a seed treatment. The consistent benefit that was obtained from the middle planting (consistent with dual purpose use) seems to occur because it is more vulnerable to fall aphid buildup, yet still retains enough yield potential to benefit from the protection provided by the seed treatment.

These results indicate that a producer is more likely to obtain a positive economic return when the seed treatment is used in the dual purpose planting window, which makes up nearly 40% of the planted acres each year. Although these results show that a positive economic return could be realized solely from the grain yield benefit, we did not evaluate the effects of these treatments on forage accumulation or quality. Investigations are currently underway to determine

Table 5. Effects of rate of imidacloprid on BYDV incidence, FHC, TW, yield, and economic return at Stillwater, OK, 2001–2002

Cultivar	Insecticide rate (g [AI]/kg seed)	% BYD	FHC	TW (kg/bu)	Yield (quintals/ha)	Profit (loss)[a]			Avg statistical[b] profit (loss)
						Low	High	Avg	
Karl 92	Untreated	85.0	19.3	21.0	27.42a				
	0.32	41.3*	31.8*	24.0*	33.95b	$39.70	$92.41	$66.06	$66.06
	0.48	16.3*	34.3*	24.6*	36.10b	$43.91	$114.02	$78.97	$52.81
	0.64	8.8*	37.8*	24.6*	38.05b	$33.25	$119.11	$76.18	$26.31
2174	Untreated	76.3	26.3	22.2	28.71a				
	0.32	25.0*	33.5*	24.5*	35.43b	$41.33	$95.67	$68.51	$66.51
	0.48	1.25*	44.3*	24.6*	41.08c	$73.94	$173.93	$123.93	$123.93
	0.64	0.0*	51.5*	25.0*	43.43c	$66.55	$185.55	$126.05	$97.43
Combined	Untreated	76.3	26.3	22.2	28.06a				
	0.32	25.0*	33.5*	24.5*	34.69b	$41.33	$95.67	$68.51	$66.51
	0.48	1.25*	44.3*	24.6*	38.598c	$73.94	$173.93	$123.93	$123.93
	0.64	0.0*	51.5*	25.0*	43.43c	$66.55	$185.55	$126.05	$97.43

Means within a column followed by an asterisk* are significantly different (P |t| < 0.05) from the corresponding untreated mean in the assigned planting date. Means within a column followed by the same letter are not significantly different ($P < 0.05$; PROC MIXED, SAS Institute 1999).

[a] Profit (loss) is calculated by subtracting the untreated yield from the treated yield in quintals/hectare, multiplying it by the low ($8.11), high ($16.18), and average ($12.15) prices that winter wheat sold for in Oklahoma from 1995 to 2001, and subtracting the cost of the seed treatment ($13.25, $26.50, or $53.00/ha).

[b] Statistical profit (loss) is calculated if yield differences are significantly (P |t| < 0.05) different from the untreated plots and each other. If different, then the difference is multiplied by the avg ($12.15) price that winter wheat sold for in Oklahoma from 1995 to 2001, and then subtracting the cost of the seed treatment. If a statistical difference was observed from the untreated check, but not among treatments, then the assigned profit (loss) is the value of the lowest significant difference in yield minus the cost of the seed treatment. If no statistical difference was observed from the untreated plots, then the profit (loss) is the cost of the seed treatment.

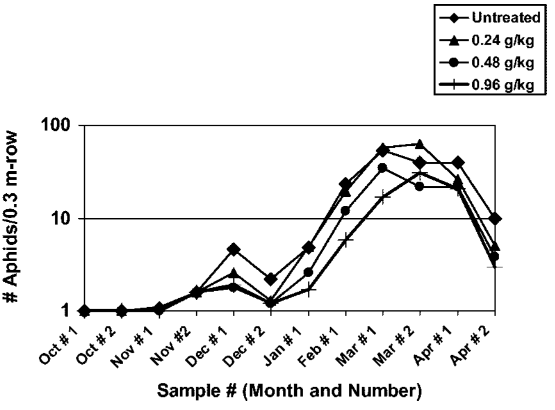

Fig. 2. Aphid abundance for each seed treatment rate in the middle planting date. Data from Lahoma and Perkins studies, 1997–1999, were combined.

the impact of feeding by *S. graminum* and *R. padi* (K.L.G. and R.H., unpublished data) on wheat forage quantity and quality. Such information would need to be factored into the economic value of seed treatments.

We did not evaluate these treatments under a true dual purpose environment where the wheat was grazed. Arnold (1981) found that the grazing activity of cattle provided some level of control of greenbug numbers in winter wheat. It was not clear whether the reduction was caused by the removal of suitable sites for establishment and feeding by greenbugs, direct mortality due to the cattle feeding, or both. However, cattle are not normally put on wheat pasture for at least 40 d after seeding emergence (Krenzer 1997) so that wheat seedlings can develop enough to physically withstand grazing. An imidacloprid seed treatment would protect seedling wheat from aphids during the early, critical period before cattle begin grazing. Additional documentation of the long-term reliability and vector potential of fall aphid infestations at various locations throughout Oklahoma would further help producers consistently attain a positive economic return from a seed treatment.

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